TOP3–00151

Improved Heteroepitaxy for Wide Band Gap Electronic Materials

Technology

A patented process to grow improved layers of wide band gap (WBG) electronic materials such as 3C-SiC, GaN, AlGaN, and InGaN.

Benefits

Today's commercially available SiC and group III nitride WBG electronic materials contain many dislocation defects. Depending upon the device application, these defects reduce the performance and/or operating life of electronic devices. Improved heteroepitaxy technology has produced defect-free heteroepitaxial layers of 3C-SiC on 4H-SiC substrates, and promises to produce improved heteroepitaxial layers of group III nitride films. These improved quality WBG materials should

- Lead to improved performance and operating life of today's WBG electronic devices
- Enable new commercially viable WBG electronic devices

Commercial Applications

- WBG electronic devices including
  - High-power switching devices for electric power conversion and management
  - High-power and high-frequency devices for radiofrequency amplifiers
  - Short wavelength light-emitting diodes (LED's) for general lighting applications
  - Short wavelength lasers for data storage applications

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Technology Description

This improved heteroepitaxy technology builds on the foundation of atomically flat technology described in TOP3–00149 (Atomically Flat Wide Band Gap Material) and TOP3–00152 (Web Growth of Silicon Carbide Surfaces). Heteroepitaxy is the process of growing layers of one material on a substrate of a different material. Imperfections in the substrate can nucleate defects, which can propagate into heteroepitaxial layers grown on the substrate. Even atomic-scale steps as small as 0.25 nanometers on the surface of the substrate material can cause defects. To eliminate layer defects arising from these surface imperfections, this improved heteroepitaxy technology starts with atomically flat SiC as the substrate for heteroepitaxial growth. Figure 1 shows a cross- sectional tunneling electron microscopy (TEM) of defect-free 3C-SiC grown on atomically flat 4H-SiC.

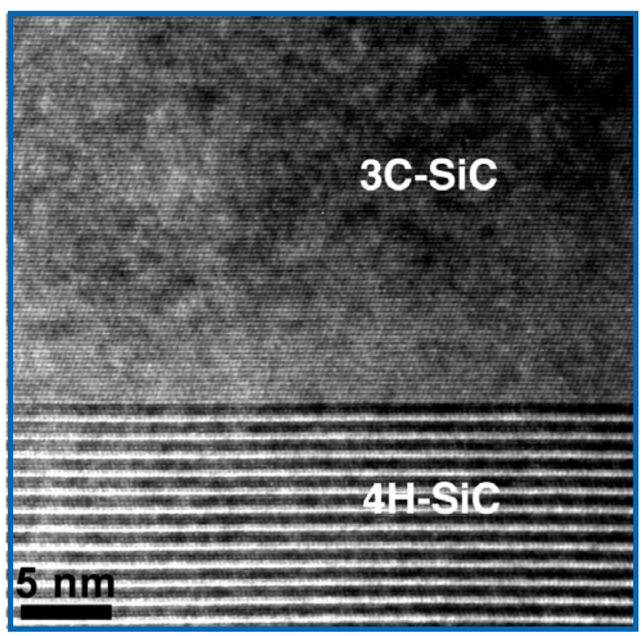

Figure 1.—TEM of defect-free 3C-SiC on atomically flat 4H-SiC. [1]

In addition to using an atomically flat surface as a substrate, this improved heteroepitaxy technology describes the nucleation and growth process required to achieve high-quality heteroepitaxial layers. Figure 2 shows an image of 3C-SiC that was grown on atomically flat 4H-SiC without the improved heteroepitaxy technology. The darker gray lines and triangles in figure 2 are evidence of defects in the 3C-SiC layer, made visible after thermally oxidizing both figure 2 and figure 3 crystals. The defect-free material shown in figure 3 was grown on a similar atomically flat substrate, but using the improved heteroepitaxy nucleation and growth conditions. NASA has begun to apply this technology to heteroepitaxial layers of group III nitride films, which are important to short-wavelength opxoelectronics. An initial experiment produced a GaN film with far fewer defects that conventional GaN films, and furthur improvements are expected with process optimization.

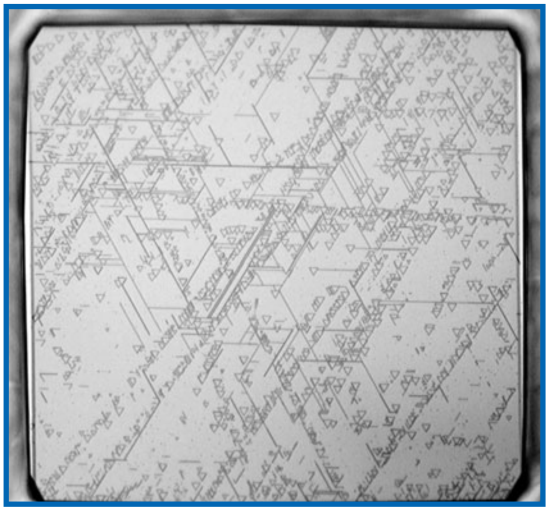

Figure 2.—3C-SiC material that was grown on atomically flat 4H-SiC without improved heteroepitaxy technology.

Figure 3.—Defect-free 3C-SiC material grown on a 0.2 mm x 0.2 mm mesa of atomically flat 4H-SiCwith improved heteroepitaxy technology.

Options for Commercialization

Initial industry contacts have expressed interest in working with this technology, and NASA Glenn is pursuing license agreements for its portfolio of wide band gap material patents and patent pending technologies.

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LEW–15223–1, 15222–3, 16374–1, 16374–2, 17116–1, 17186–1, and 17187–1.

U.S. Patent 5,248,385; 5,363,800; 5,915,194; and 6,165,874, 6,461,944, 6,488,771.

Key Words

Wide band gap	Silicon carbide
Gallium nitride	Blue laser
High-power electronics	Materials